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REMOVAL OF IRON (Fe^{2+}) BY OXIDATION THROUGH NATURAL AND AERATED LAGOON

DISSERTATION

BY

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8068

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CERTIFICATION OF APPROVAL

Removal of Iron (Fe^{2+}) from Groundwater by Oxidation through Normal and Aerated Lagoon

by

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Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
(Civil Engineering)

Approved by,

(AP Dr. Nasiman Sapari)
Project Supervisor

UNIVERSITI TEKNOLIGI PETRONAS

TRONOH, PERAK

JUNE 2010

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references, and that original work contained herein have not been undertaken or done by unspecified sources or persons.

(ABDUL QADIR BIN JAILANI)

ABSTRACT

This research is focusing on removing iron (II) from groundwater by oxidation through normal and aerated lagoon. The experiment will focuses to find the optimum pH of sample based on the different pH. From the experiment conducted, the optimum pH is at pH7. The desired colour also is another factor why pH7 is considered as optimum pH. For example, even though the colour of pH2 is within the allowable limit, but the iron concentration is high due to zero precipitation observation during experiment. Another consideration that needs to stress is cost. The cost will main factor doing any treatment water. Even though there is more modern technology, the cost will be high because the technology is limited. In addition, the conventional treatment can save a lot of money.

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CHAPTER 1

INTRODUCTION

1.0 INTRODUCTION

1.1 Research Background

1.1.1 Groundwater

Groundwater is water located beneath the ground surface in soil pore spaces and in the fractures of lithologic formations. A unit of rock or an unconsolidated deposit is called an aquifer when it can yield a usable quantity of water. The depth at which soil pore spaces or fractures and voids in rock become completely saturated with water is called the water table. Groundwater is recharged from, and eventually flows to, the surface naturally; natural discharge often occurs at springs and seeps, and can form oases or wetlands. Groundwater is also often withdrawn for agricultural, municipal and industrial use by constructing and operating extraction wells. The study of the distribution and movement of groundwater is hydrogeology.

Typically, groundwater is thought of as liquid water flowing through shallow aquifers, but technically it can also include soil moisture, permafrost (frozen soil), immobile water in very low permeability bedrock, and deep geothermal or oil formation water. Groundwater is hypothesized to provide lubrication that can possibly influence the movement of faults. It is likely that much of the Earth's subsurface contain some water, which may be mixed with other fluids in some instances.

1.1.2 Issues of Groundwater

Most of water supply demand uses surface water such as river, stream, lake, wetland or ocean. But the increasing of population growth rate in Malaysia is about 1.742% for 2008. Population growth rate is defined as the average annual percent change in the population, resulting from a surplus or deficit of births over deaths and the balance of migrants entering and leaving a country. The rate may be positive or negative. The growth rate is a factor in determining how great a burden would be imposed on a country by the changing needs of its people for infrastructure (e.g., schools, hospitals, housing, roads), resources (e.g., food, water, electricity), and jobs. Rapid population growth can be seen as threatening by neighboring countries (Source:- CIA World Factbook). The increasing of population will be increasing the water supply demand. To overcome the problem, groundwater needs to be exploited. Groundwater development in Malaysia is lagging because there is a failure to recognize the vast potential of the invisible groundwater resource, said Natural Resources and Environment Minister Datuk Douglas Uggah Embas (Ng Cheng Yee, 2009). The wise use of groundwater resources can play a significant role in supplementing the national water supply requirement and reducing the impact of drought in both urban and rural environments.

The problem faced in groundwater supply is to remove iron (II) from groundwater. There were several researches or studies have done a few years ago to find the solution to remove iron (II) in the groundwater using carbon. The type of carbon have been use are granular activated carbon (Jusoh A. et al., 2005) and impregnated activated carbon (Okoniewska E. et al., 2006)

1.1.3 Groundwater Quality

The treatment cost of groundwater could be cheaper than the treatment of surface water. Besides the advantage of low turbidity, it also contains nutrients which are good for health. (Mohammed T. A. et al., 2009). Generally, the concentration of iron (II) in groundwater was found to be higher than the allowable limit which is 0.3 mg/L of iron (II) concentration (Guideline for Drinking Water Quality, World Health Organization (WHO), 2008, page 216).

Malaysia Environmental Quality Report 2006 stated that there are 122 monitoring wells had been established at 48 sites in Peninsular Malaysia, 19 wells in Sarawak and 15 wells in Sabah (see **Table 1.1**). The sites were selected and categorized according to the surrounding land uses which were agricultural, urban/suburban, rural, industrial, solid waste landfills, golf courses, radioactive landfill, animal burial areas, municipal water supply and examining areas (gold mine). **Table 1.1** shows the distribution of groundwater monitoring wells for 2006.

Table 1.1:- Distribution of Groundwater Monitoring Wells, 2006

Category	Number of Wells
Agricultural Areas	12
Urban/Suburban Areas	12
Industrial Sites	18
Solid Waste Landfills	27
Golf Courses	7
Radioactive Landfill	1
Rural Area	5
Ex-mining Area (Gold Mine)	3
Municipal Water Supply	11
Animal Burial Areas	16
Aquaculture Farms	9
Resorts	1
Total	**122**

1.1.4 Groundwater Usage

In Malaysia, the usage of groundwater is still low compared to the other countries. The usage of groundwater in Malaysia is less than 2% to compare with Thailand that used 80% of groundwater, Austria (98%), Denmark (100%) and China (78%).The groundwater storage is estimated to be 5000 billions m^3(Azuhan, 1999). **Table 1.2** shows the summary of the water resources in Malaysia.

Table 1.2:- Water resources in Malaysia

Water resources	**Quantity (billion m^3)**
Annual rainfall	1046
Surface runoff	566
Evapotranspiration	360
Groundwater recharge	120
Surface artificial storage	25
Groundwater Storage	**5000**

1.1.5 Occurrence of Iron

As we know, iron reacts with dissolved oxygen to form insoluble compounds. Generally, surface water does not contain large amounts of iron because surface water contains high amounts of dissolved oxygen.

Iron is found frequently in water system that obtains water from wells and springs.

1.2 Problem Statement

The increasing growth rate will increase the water supply demand. For country like Malaysia which usually use surface water to fulfill the water supply demand. In the future, surface water is not enough to fulfill the water supply demand. The government of Malaysia should find another source of freshwater such as groundwater or water from sea. The main problem of using sea water is the cost of treatment is high. The cost of treatment for groundwater should be cheap because of low turbidity and groundwater also has some good minerals for human.

Generally, groundwater found in many countries, including Malaysia contains high level of iron (II) concentration. As stated in Guideline for Drinking Water Quality by WHO, the allowable limit for iron concentration is 0.3 mg/L. High concentration of iron could be harmful to human in the long term.

This research will focus on the removal of iron from groundwater to meet the standard by WHO. The removal of iron is through carbonaceous shale filtration to improve the quality of groundwater by removing the iron (II) in the groundwater. This research will go through several experiment to prove carbonaceous shale can remove iron from groundwater. Before running the experiment, the groundwater from other places must be analyses to support the main objective which is to remove iron (II) from groundwater. Experiment will be conduct to find the efficiency of carbonaceous shale to remove iron (II) from groundwater.

1.3 Objective

The following is the objective of this research:-

a) To find the optimum pH to remove iron concentration by oxidation through normal and aerated lagoon.

1.4 Scopes of the Research

This research will be focuses in several activities in order to fulfill the objectives. The scopes of the study as followings:-

a) Kinetic study on the iron solution sample.
b) Groundwater quality analysis.

CHAPTER 2

LITERATURE REVIEW

2.0 LITERATURE REVIEW

2.1 Groundwater

Water resources are sources of water that are useful to human daily life. The users of water are from household, agricultural areas, industrial areas etc. In daily life, especially in domestic usage, freshwater is thoroughly used for drinking, washing etc. It is the main source of water supply for certain country to fulfill the water supply demand. In Canada, 26% of the population (approximately 8.58 million), mostly living in small rural communities are depending on the groundwater for their domestic needs (Ellis D. et al., 2000). In USA, about 21% (69.8 billions gallon per day) water used came from groundwater (Perlman H., 2009).

In Malaysia, less than 2% of groundwater has been used, mostly in rural area. This is because the lacking of extensive groundwater. The following are reasons for the lacking of extensive groundwater development in Malaysia:-

a) The failure to recognize the vast potential of the groundwater resources.
b) The misconception of that groundwater exploitation is not sustainable.
c) The lack of full assessment of the groundwater resources.

The use of groundwater for domestic purposes is mainly confined to rural areas because of no piped water supply connected. However, groundwater is being significantly

utilized for public water supply such as in Kelantan and Perlis. The other states, which supplement the water supply systems groundwater, are Terengganu, Pahang, Sarawak and Sabah. In Kelantan, groundwater plays a very important role in the public water supply system. About 70% of the total water supply in the state is derived from groundwater, primarily in the Kota Bharu areas. The rural population is highly dependent on groundwater for their daily requirements, and they obtain it from the shallow dug wells. In Malaysia and during the 1998 dry spell, groundwater has provided relief for the people, especially in Selangor and Sarawak. So, there is a great potential in the use groundwater supplies to meet the increasing demand, and for this reason, a special emphasis must be given to sustainable development of groundwater. (Mohammed T. A. et al., 2009).

2.2 Groundwater Quality

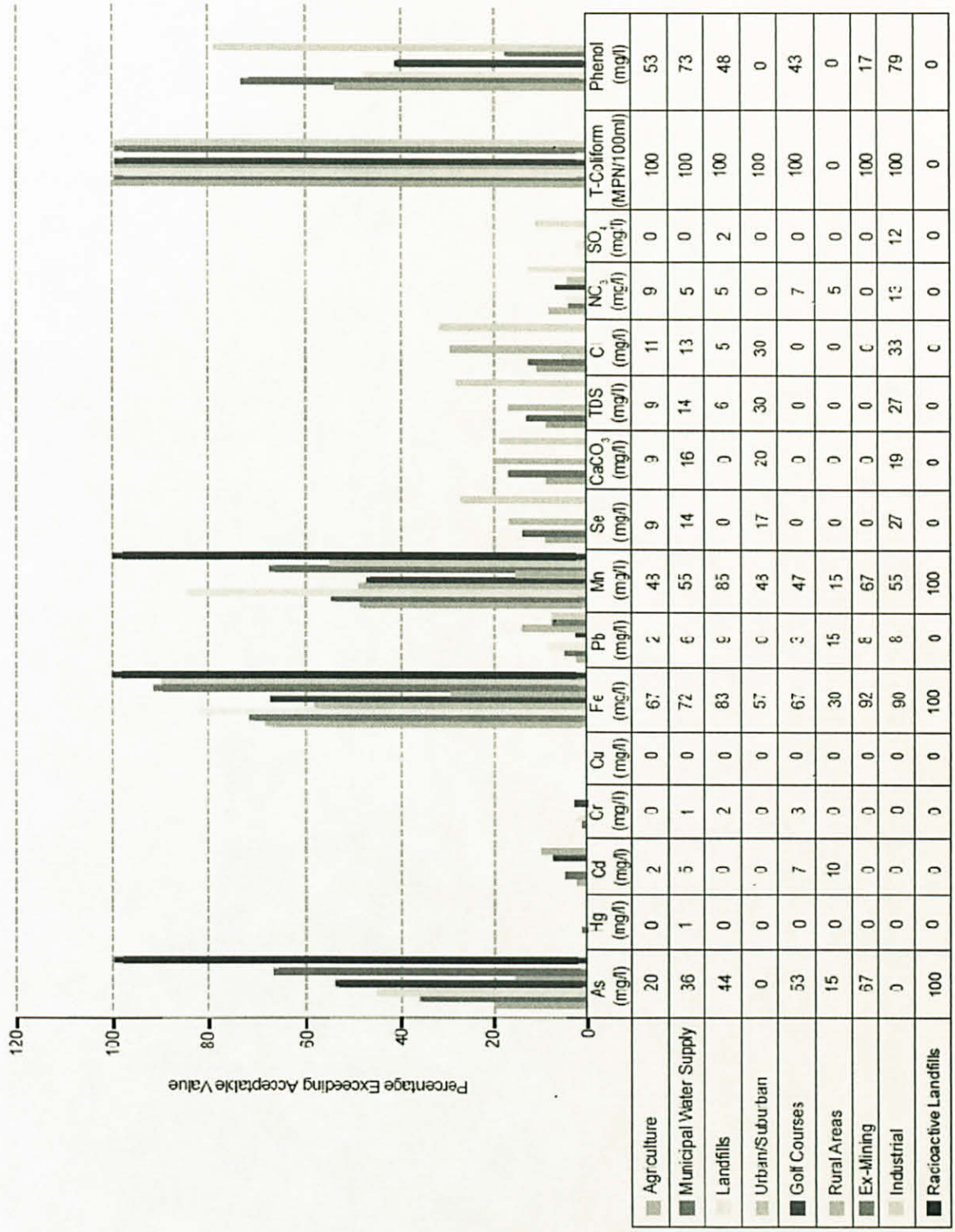
Based on Malaysia Environmental Quality Report 2006, in 2006, 340 water samples were taken from these monitoring wells compared to 250 in the previous year (2005). The samples were analyzed for volatile organic compounds (VOCs), pesticides, heavy metals (such as iron), anions, bacteria (coliform), phenolics compounds, radioactivity (Gross Alpha and Beta), total hardness, total dissolved solids (TDS), pH, temperature, conductivity and dissolved oxygen (DO). The groundwater quality status was determined based on the National Guidelines for Raw Drinking Water Quality from the Ministry of Health (Revised December 2000) (see **Table 2.1**).

Iron levels exceeding the benchmark were recorded in all samples (see **Figure 2.1**). Between 30 percent and 100 percent of the samples taken from all sites showed high levels of iron which are exceeding the benchmark (0.3mg/L). The sampling results also showed that between 15 percent and 100 percent of samples taken from all areas recorded manganese (Mn) levels exceeding the benchmark. Between 5 percent and 13 percent of samples in rural areas (5%), landfills (5%), municipal water supply (5%), golf courses (7%), agricultural areas (9%) and industrial areas (13%) were found to exceed the nitrate benchmark except in urban/suburban, ex-mining areas and radioactive

landfills. Arsenic levels exceeding the benchmark were recorded at radioactive sites (100%), ex-mining areas (67%), solid waste landfill (44%), municipal water supply (36%) and agricultural areas (20%). Other parameters exceeding the acceptable values are shown in **Figure 2.1.**

Table 2.1:- National Guidelines for Raw Drinking Water Quality
(Revised December 2000)
(for hardness, total dissolved solids(TDS) and iron)

Parameter	**Symbol**	**Benchmark**
Sulphate	SO_4	250 mg/L
Hardness	$CaCO_3$	500 mg/L
Nitrate	NO_3	10mg/L
Coliform	-	Must not be detected in any 100ml sample
Manganese	Mn	0.1 mg/L
Chromium	Cr	0.05 mg/L
Zinc	Zn	3 mg/L
Arsenic	As	0.01 mg/L
Selenium	Se	0.01 mg/L
Chloride	Cl	250 mg/L
Phenolics	-	0.002 mg/L
TDS	-	1000 mg/L
Iron	Fe	0.3 mg/L
Copper	Cu	1 mg/L
Lead	Pb	0.01 mg/L
Cadmium	Cd	0.003 mg/L
Mercury	Hg	0.001 mg/L



	As (mg/l)	Hg (mg/l)	Cd (mg/l)	Cr (mg/l)	Cu (mg/l)	Fe (mg/l)	Pb (mg/l)	Mn (mg/l)	Se (mg/l)	$CaCO_3$ (mg/l)	TDS (mg/l)	Cl (mg/l)	NO_3 (mg/l)	SO_4 (mg/l)	T-Coliform (MPN/100ml)	Phenol (mg/l)
Agriculture	20	0	2	0	0	67	2	43	9	9	9	11	9	0	100	53
Municipal Water Supply	36	1	5	1	0	72	6	55	14	16	14	13	5	0	100	73
Landfills	44	0	0	2	0	83	9	85	0	0	6	5	5	2	100	48
Urban/Suburban	0	0	0	0	0	57	0	43	17	20	30	30	0	0	100	0
Golf Courses	53	0	7	3	0	67	3	47	0	0	0	0	7	0	100	43
Rural Areas	15	0	10	0	0	30	15	15	0	0	0	0	5	0	0	0
Ex-Mining	67	0	0	0	0	92	8	67	0	0	0	0	0	0	100	17
Industrial	0	0	0	0	0	90	8	55	27	19	27	33	13	12	100	79
Radioactive Landfills	100	0	0	0	0	100	0	100	0	0	0	0	0	0	0	0

Figure 2.1:- Percentage of Non Compliance of Selected Contaminants by Land Use, 2006

2.3 Iron in Drinking Water

In general, iron is the second most abundant metal in the earth's crust which accounts approximately 5%. Iron is commonly found in nature in the form of its oxides. Based on earlier research and study all over the world, the iron concentration in the groundwater is up to 15mg/L. As stated in the Guideline for Drinking Water Quality by WHO, the iron concentration in the drinking water must not exceed 0.3mg/L. The groundwater must be treated before it can be used in daily life activities.

Iron is an essential element in human nutrition. Minimum daily requirement for iron is estimated based on the age, sex, physiological statues and iron bioavailability which are range from 10 to 50 mg/L. To prevent excessive storage of iron in the body, in 1983, Joint FAO/WHO Expert Committee on Food Additives (JECFA) established a Provisional Maximum Tolerable Daily Intake (PMTDI) of 0.8 mg/kg of body weight which applies to iron from all sources except iron oxides used as coloring agents, iron supplements taken during pregnancy, and lactation or for specific clinical requirements. Excessive iron can be harm to human being. (Iron in Drinking Water, Background document for development of WHO Guidelines for Drinking Water Quality, 1996)

2.4 Current Treatment Based On Research or Study

Other countries also faced same problem with the iron concentration exceeding the allowable limit. Few years ago, there are several researches or studies have done before to remove iron in the groundwater to be utilized.

The iron concentration that has been traced in groundwater between seven (7) to 15 mg/L found in Quebec, Canada. The treatment has been used to remove iron were by oxidation and microfiltration. The process has been use is the oxidation of ferrous iron with oxygen. The water samples were oxygenated by air bubbling and the pH was adjusted to 8.1±0.1 with sodium hydroxide (NaOH) in order to fasten the oxidation of

iron for which 15 minutes were allowed to ensure complete iron oxidation. The result indicated by the absence of any significant amount of dissolved iron (≤0.45μm), the oxidation of iron with oxygen, at pH 8 and at 8°C, was achieved with few minutes. The set-up is a usual membrane laboratory set-up. The result of this microfiltration shows that the iron concentration of the microfiltration permeates stayed below 0.1mg/L which is the detection limits. A number of permeate was above 0.1mg/L, but this concentration value can probably be explained as sampling errors since they were randomly dispersed throughout the analyses. These results are coherent with those of (Côté et al., 1998) who reported total retention of iron oxide in a full scale plant with a 0.1μm microfiltration membrane. This confirms that microfiltration is a very efficient separation process for iron oxide particles, even for groundwater with high level of iron concentration. (Ellis D. et al., 2000).

A case study from a treatment unit has been done in northern Greece. The objective of this case study is to remove arsenic from groundwater containing iron, ammonium, manganese and phosphate. In Greece, the presence of compounds in drinking water is regulated by Drinking Water Directive of the European Council (98/83/EC) on the quality of water intended for human consumption. According to this directive, the parametric value for iron concentration is 200μg/L. The removal of iron is generally accomplished by chemical or biological oxidation (Katsoyiannis and Zouboulis, 2004). The results show that the presence of iron is typical of reducing conditions with concentration of iron around 165μg/L. Concentration of iron is below the current EC parametric value which is 200μg/L.

The other study was done in Malaysia. The purpose of the study is to study on the removal of iron and manganese in the groundwater by granular activated carbon. The granular activated carbon has been crushed, sieved, washed, rinsed and sealed before the granular activated can be used in the experiment. The test was conducted by mixing certain amount of processed granular activated carbon with 200ml of aqueous solution in the beaker and shook at 150rpm in room temperature until equilibrium is reached. The various dosage of granular activated carbon has been tested between 0.1 and 0.6mg for

iron. The preliminary experiment showed that equilibrium was attained after 6 hours. The result showed that the adsorption capacity of iron were 3.6010mg/g. In the conclusion stated that the adsorption of iron that performed granular activated carbon was very encouraging. (Jusoh A. et al., 2005)

Poland also implements the European directives concerning water purification into the Polish Law the threshold value of iron in water has decreased which iron is 0.2mg/dm^3. The iron occurs in water mostly as carbonates, sulfates, humic compound, chlorides and sometimes phosphates. The efficiency of the influence of pH solution and the initial concentration of iron on sorption effects was determined. The activated carbon was impregnated by the solution of $KMnO_4$ in the 64 g/dm^3 concentration. 1g of impregnated activated carbon was prepared with iron in the flask containing 250cm^3 water. Then continue the experiment carried out under flow conditions. The aim of this experiment was to estimate the influence of the initial concentration of iron on the sorption effect and to determine the influence of filtration speed on the contaminant removal efficiency from water. The result showed that the adsorption of iron on impregnated activated carbon is a complex process and it depends on the initial concentration of iron as well as on the pH and filtration speed. The adsorption capacity of impregnated activated carbon for iron is between 1.0 to 1.5 mg/dm^3 (mg/L) at pH 9. (Okoniewska E. et al., 2006).

2.5 Carbonaceous Shale

Sedimentary rocks are rocks that formed by cementation of transported and sediment materials derived from the physical and chemical breakdown of the pre – existing rocks, or from diverse chemical or biological process.

Shale is used for the claystones with fissility. Fissility is the tendency to split along closely spaced, roughly planar surfaces that are essentially parallel to bending. Shale is frequently named on the basis of their color, some compositional characteristic, or degree of development of their fissility.

The black shale is frequently referred as carbonaceous shale due to the carbon content inside the shale itself. The shale is usually black due to the presence of partially decayed remains of the plants and animal commonly deposited with clay – rich sediment. Total organic carbon (TOC) contents typically range from 1 to 15%. The deposition of black organic – rich shale is favored if surface – water productivity is high and/or terrestrial – plant material is introduced in abundance.

Carbonaceous shales contain pyrite or marcasite, which are thought to be of digenetic origin with their sulphur derived from the hydrogen sulphide that was given off by organic matter buried in the patent clay.

In previous researches, carbon was used as main component to remove iron. (See sub-topic **2.4**). In the water treatment industry, they also were using carbon to remove iron such as activated carbon filter. Activated carbon (AC) works by attracting and holding certain chemicals as water passes through it. Activated carbon is a highly porous material; therefore, it has an extremely high surface area for contaminant adsorption. The equivalent surface area of 1 pound of AC ranges from 60 to 150 acres (Source:- **Clear-Ion Experts (P) Ltd.**).

In this research, the carbonaceous shale will be tested on iron removal. In order to design the filter, several experiments will be conducted to determine unknown information that is related to this research.

CHAPTER 3

METHODOLOGY

3.0 METHODOLOGY

3.1 Procedure Identification

In order to complete this research successfully, a systematic and structural research methodology is crucial. Thus, a thorough discussion was held with the supervisor to address this issue. When deciding on the research title, a brief study on the research title been held. This is to get a general/rough idea on the study area of this title. Upon completion on this study, a thorough literature survey thru all the available sources such as internet, online or printed journals, reference books and discussion with the supervisor. This definitely gives a deeper and more profound understanding on the topic. As the research progress, more literature reviews and discussion will be held to address all the arising problems. The research methodology can be generally divided into two main parts which are the first semester and the second semester. The literature review, gathering information, research and deciding on locations of assessment are the main target for the first semester, and the analysis of assessment and compiling of information are set for the second semester.

3.2 Flowchart

The following flowchart explains the methodology in executing the research:-

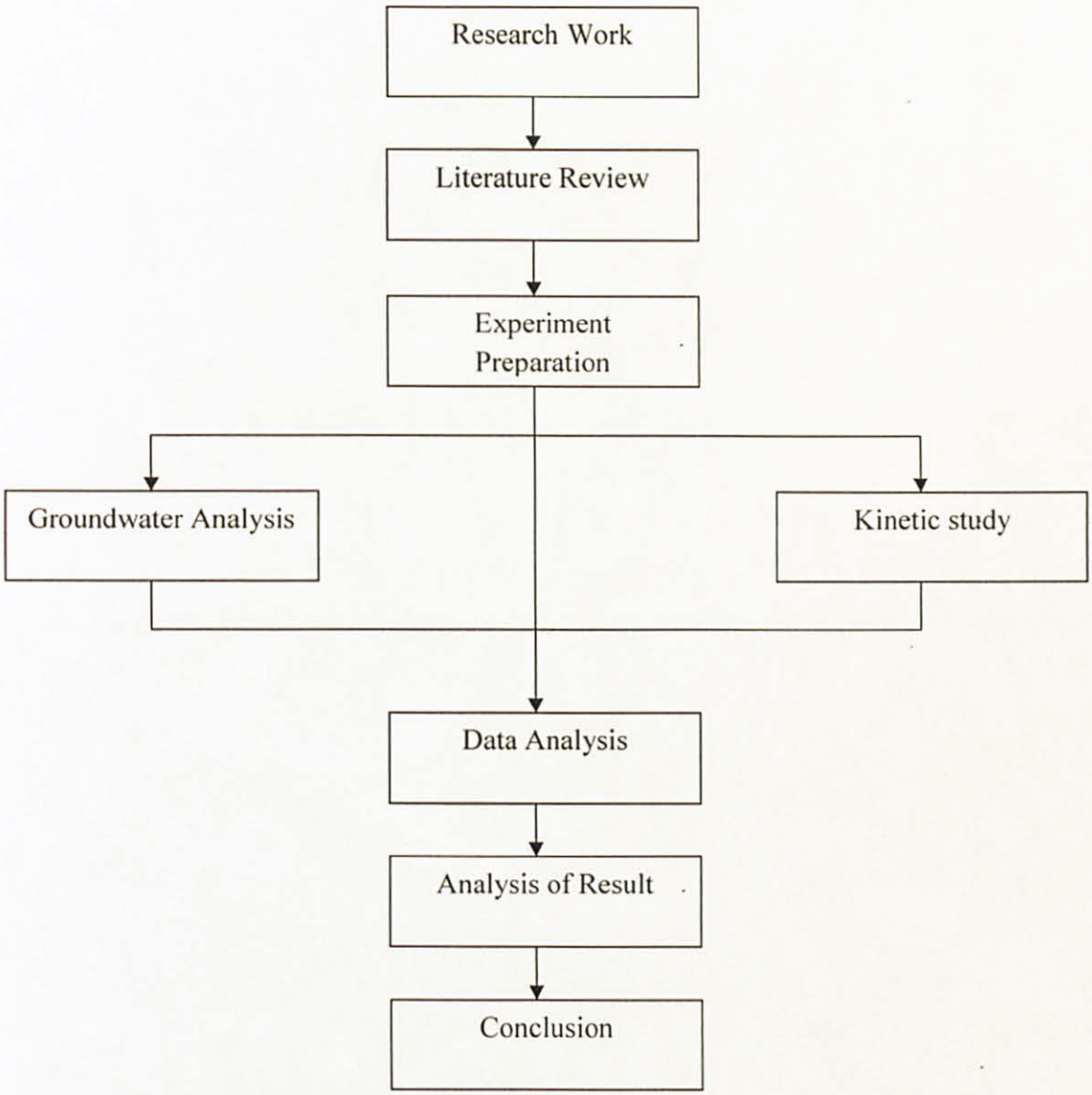


Figure 3.1:- Research Flowchart

3.3 Literature Review

The literature review involves discussing on:-

a) Definition of groundwater,
b) Groundwater quality
c) Iron in drinking water
d) Current treatment based on research or study

3.4 Experimental Procedure

The experimental will be conducted based on the scope of research have been discussed in **Chapter 1.4**.

3.4.1 Groundwater Analysis

Groundwater from UTP well has been analyzed. The criteria that have been determined are total iron for iron concentration and pH. The methodology of iron concentration and pH will be explained in **Chapter 3.4.3 and 3.4.4**.

3.4.2 Kinetic Study on Iron Solution Sample

There are three (3) samples of iron solution with different type of experiment know as normal lagoon. Each sample contains iron solution from pH2 until pH10. For each sample, to prepare the iron solution sample, five (5) ml from iron standard with 1000 mg/L of iron concentration is added in one (1) liter. Then, distilled water is added into the assign beaker up to one (1) liter mark. By adding five (5) ml and 995 ml of distilled water, the normal pH is about pH2.5.To increase pH to pH3 until pH10, the sample were added with one (1) drop of sodium hydroxide (NaOH) and powder sodium bicarbonate ($NaHCO_3$).

Each sample is using different number of experiment except for time interval. The assigned time for each sample as below:-

a) Zero (0) minute (initial reading)
b) Five (5) minute
c) 30 minutes (half an hour)
d) One (1) hours
e) Three (3) hours
f) Six (6) hours
g) 24 hours

To compare result, another type of experiment is created which is aerated lagoon. The different of this experiment is volume of each pH, and assigned time. The normal lagoon is use 5mL of iron solution and added with 450mL distilled water in 500mL beaker. For aerated lagoon, volume of sample is 1000mL which contain 10mL of iron solution and added with 990mL of distilled water. The assigned time for each pH as below:-

a) Zero (0) minute (initial reading)
b) One (1) hour
c) Two (2) hours
d) Three (3) hours
e) Four (4) hours
f) Five (5) hours

g) Six (6) hours

h) 24 hours

Aeration process will start immediately after samples reach the selected pH. Aeration process will take 30minutes and another 30minutes to allow settlement process. The rate for aeration process is 0.6 mL/hr or 0.03 L/hr. This step is same with other time except for aeration process reading 24 hour. After reading of 6 hour taken, the aeration process will be continue and need to be stop before 24 hour of time to allow settlement process happen.

The different number of experiment for each sample is tabulated as below:-

Table 3.1: Experiment for each sample

Experiment	Sample 1	Sample 2	Sample 3
pH (initial)	✔	✔	✔
pH (after 1 day)	-	✔	✔
Total iron (initial)	✔	✔	✔
Total iron (after 1 day)	-	✔	✔
Colour (initial)	-	✔	✔
Colour (after 1 day)	-	✔	✔

3.4.3 Determination of pH for each pH for each sample

pH was determined using pH meter by HACH sension2 pH ISE meter. After iron solution has been prepared, pH will be determined and data will be record.

3.4.4 Determination of total iron for each pH for each sample

Total iron was determinate using spectrophotometer by HACH DR 2800. Program 265 Iron, FerroVer have been used to determine the total iron from the sample for each assigned time interval as mentioned above. The scope and application is for water, wastewater, and seawater; digestion is required to determining total iron. The allowable range the spectrophotometer to read total iron is between 0.02 and 3.00 mg/L. Before the iron concentration recorded, the iron solution for each sample must be diluted because the iron concentration each sample is higher than 3.00 mg/L.

25 ml from each sample were diluted into 250 ml conical flask. The flask will be filled up to the 250 ml mark with distilled water. Then, mix well the dilution sample. After the dilution sample has been prepared, the dilution sample will be filled into 10 ml sample cell to ensure the accuracy of result. To increase the accuracy of the result, three (3) readings will be recorded to determine the average of the iron concentration. The filled sample cell will be filled up by one (1) FerroVer Iron Reagent Powder Pillow. The sample cell must be swirl to ensure all powder has been dissolved. Three (3) minutes reaction period determine by using instrument timer to make sure the reaction between powder and sample is complete. During this reaction period, an orange colour will be form, if iron is present in the sample. The blank sample also prepared with the same prepared dilution sample. Sample cell was wiped to remove water spots and fingerprints to ensure the accuracy of result. After the timer expires, the blank sample insert to the cell holder to "ZERO" the instrument. The display will show "0.00 mg/L Fe". Then, insert the prepared sample into the cell holder and "READ". The result will show in mg/L Fe.

Plate 3.1:- 10ml of sample fill into sample cell

Plate 3.2:- FerroVer Iron Reagent Powder Pillow

Plate 3.3:- Orange colour was formed

Plate 3.4:- The concentration of iron for each sample was recorded

3.4.5 Determination of colour for each pH for each sample

Another criterion to determine is colour. The scope and application is for water, wastewater and seawater; equivalent to NCASI 253 method for pulp and paper effluent using 465nm (requires pH adjustment). The program used is Program 120 Colour, 455nm. Before colour is read, filter apparatus (0.45 micron membrane filter, filter holder, filter flask, and aspirator) need to rinse using 50ml deionized water. Then, filter another 50ml deionized water to prepare the blank sample. Discard the excess water in the flask. When the sample is ready, filter 50ml of sample through the filter. Fill the sample cell with 10ml of filtered sample. Sample cell was wiped to remove water spots and fingerprints to ensure the accuracy of result. The blank sample insert to the cell holder to "ZERO" the instrument. The display will show "0.00 PtCo". Then, insert the prepared sample into the cell holder and "READ". The result will show in PtCo.

CHAPTER 4

RESULT AND DISCUSSION

4.0 RESULT AND DISCUSSION

4.1 Expected Results or Findings

From the surveys and readings, the result of removing iron from groundwater is excellent. This was based on the previous researches or studies and current development in the industry using carbons to treat the water especially in removing iron.

4.2 Experimental Results for Groundwater Quality for UTP well

4.2.1 Determination of Iron Ferrous in sample

The average iron concentration is 0.88 mg/L (see **Appendix A**). According to Guidelines Drinking-water Quality by WHO, the maximum allowable iron concentration for drinking water is 0.3 mg/L. The result show that iron concentration is high 0.58 mg/L or 193% higher than benchmark.

4.2.2 Determination of turbidity in sample

The average turbidity is 45.5 NTU (see **Appendix B**). According to Guidelines Drinking-water Quality by WHO, the maximum allowable turbidity for drinking water is

5 NTU. The reading of sample is too high from the allowable value for turbidity. The result show that iron concentration is high 40.5 NTU or 810% higher benchmark.

4.3 Experimental Results for Experiment Sample (Normal and Aerated Lagoon)

4.3.1 Effect of Initial Iron Concentration with pH

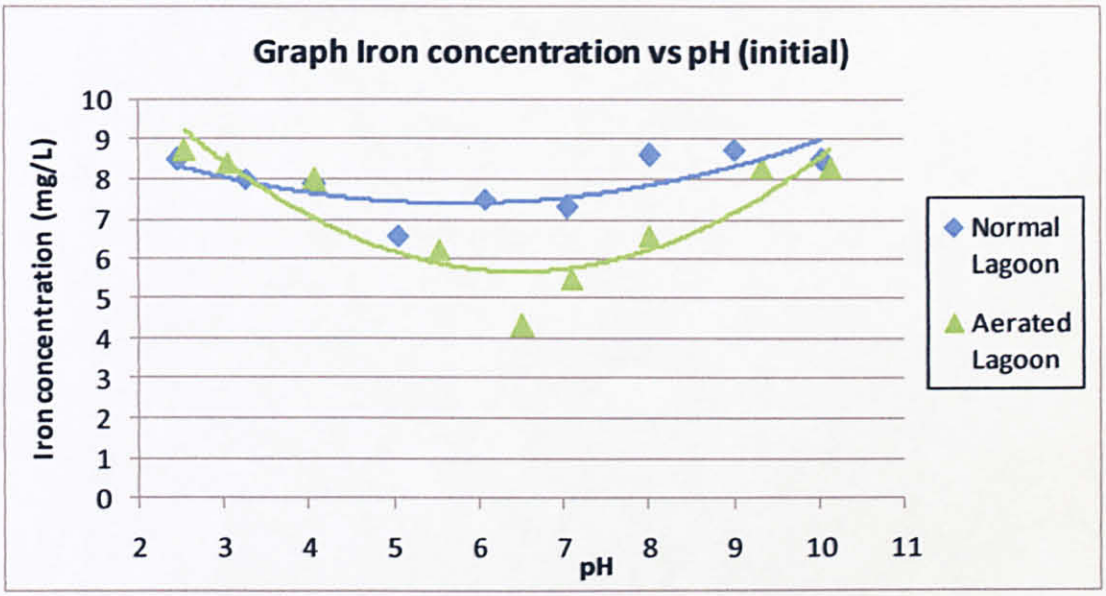


Figure 4.1: Graph iron concentration vs. pH (initial reading)

Figure 4.1 showed the relation between iron concentration (initial reading) and pH for normal and aerated lagoon. From graph, the initial readings for two (2) samples are slightly different based on the exponential graph given. For pH2, 3, 4, 9 and 10, there is no big different in iron concentration value. For pH5, 6, 7 and 8, there are big different value especially for ph7 that bring the exponential graph different for normal and aerated lagoon. It may cause by amount of solution that have been use during experiment.

For normal lagoon detail result, the result is attached at **Appendix C**. For aerated lagoon detail result, the result is attached at **Appendix D**.

4.3.2 Effect of Iron Concentration after One (1) Day with pH

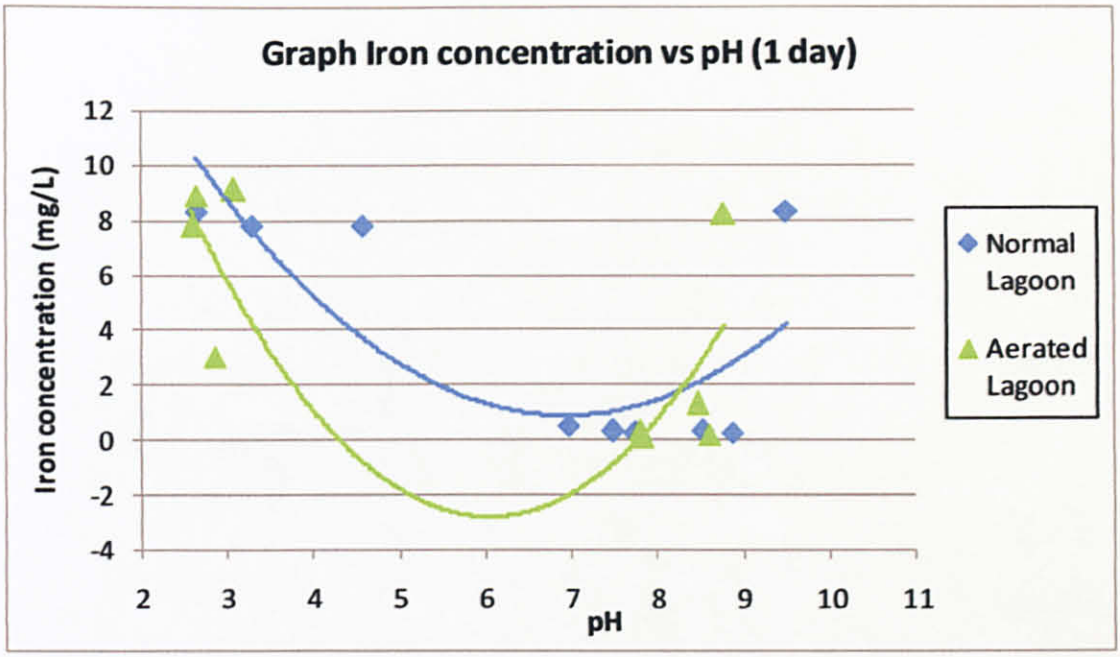


Figure 4.2: Graph iron concentration vs. pH (after 1 day)

Figure 4.2 showed the relation between iron concentration (after one day) and pH for normal and aerated lagoon. From the graph, the readings of iron concentration after one (1) day for two (2) samples are almost the slightly different on the exponential graph given. Based on the available data, for normal lagoon, the reading of iron concentration from pH5 until pH8 is between 0.5 mg/L and 0.2 mg/L. From pH2 until pH4 and pH9 until pH10, iron concentration is more than 5.0 mg/L which exceed desirable result except for Sample 1 at pH9, iron concentration is 1.8 mg/L. Aerated lagoon data showed that pH 5 until 9, the value of iron concentration is between 0.10 mg/L and 0.35 mg/L. For pH2, 3, 4, 5 and 10, the value of iron concentration is more than 3.00 mg/L which exceed allowable limit.

4.3.3 Effect of Iron Concentration with Time

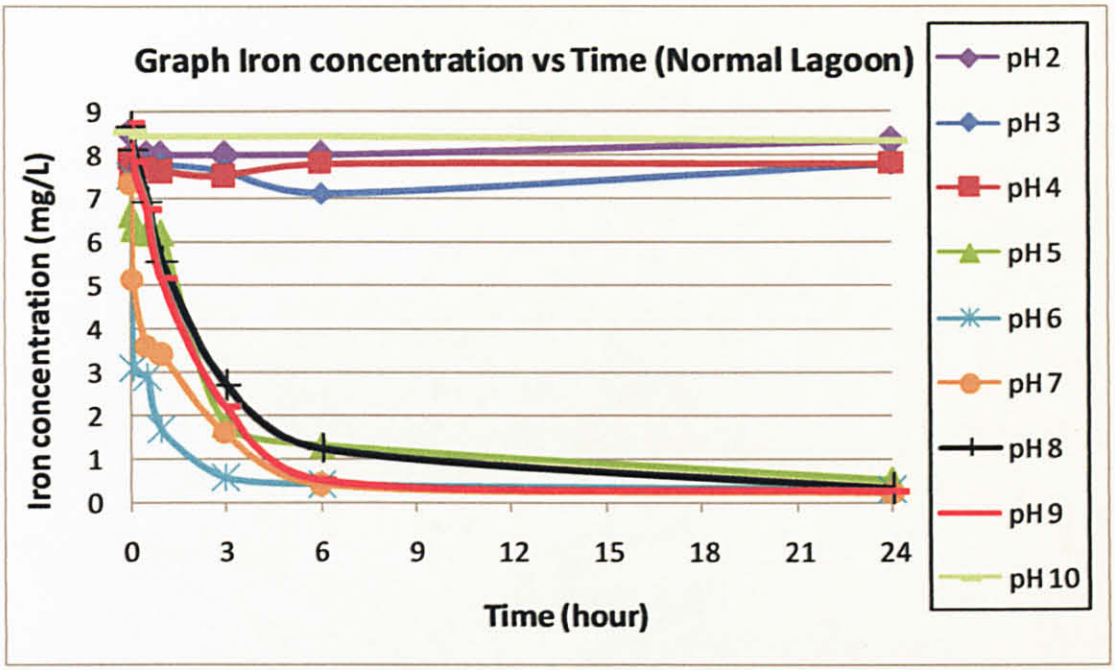


Figure 4.3: Graph iron concentration vs. time (normal lagoon)

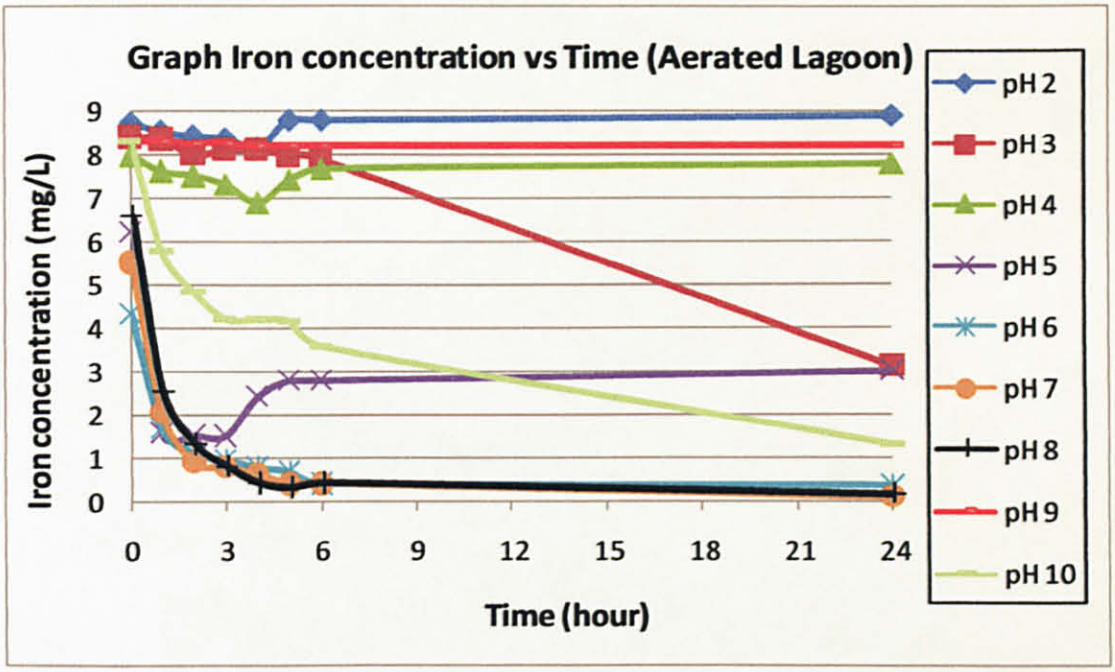


Figure 4.4: Graph iron concentration vs. time (aerated lagoon)

Figure 4.3 and 4.4 showed the relation between iron concentration and time for normal and aerated lagoon. By comparing value of iron concentration for pH6, 7 and 8 after 24 hour, for normal lagoon, the iron concentration is between 0.20 mg/L and 0.30 mg/L and for aerated lagoon; the iron concentration is between 0.10 mg/L and 0.35 mg/L. The other pH for both samples can not be used because the value of iron concentration is exceeding allowable limit.

4.3.4 Effect of Iron Concentration with pH

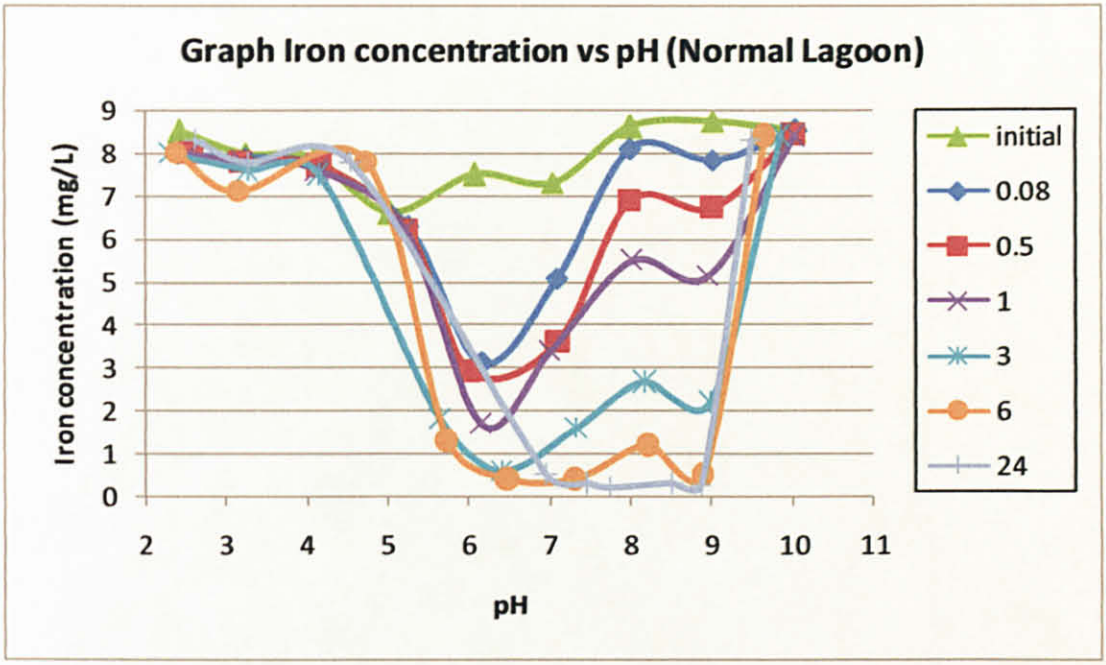


Figure 4.5: Graph iron concentration vs. pH (normal lagoon)

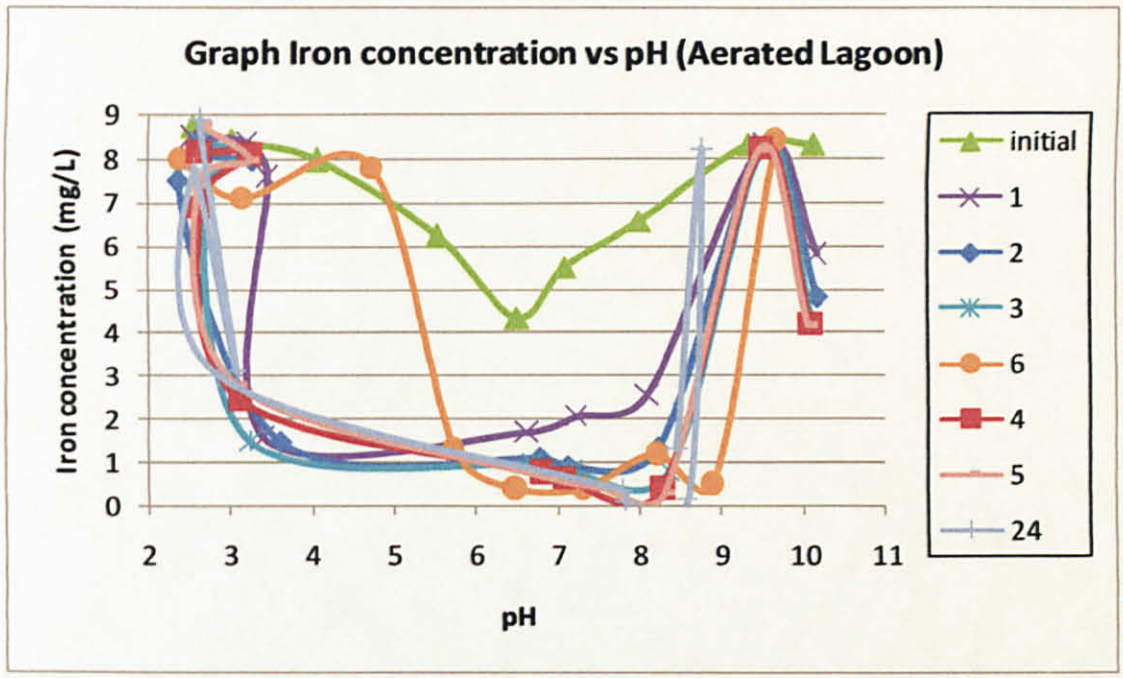


Figure 4.6: Graph iron concentration vs. pH (aerated lagoon)

Figure 4.5 and 4.6 showed the relation between iron concentration and pH for normal and aerated lagoon. For normal lagoon, the pattern of graph showed that iron concentration reach allowable limit after 24 hour. It is only applicable for pH7 and pH8. The pattern for each time line is almost same with other time line at each pH.

For aerated lagoon, the pattern showed that sample start decrease the iron concentration after 30minutes of aeration process. The iron concentration is reach allowable limit after 24 hour which applicable for pH7 and pH8. For pH9, there is no big difference from initial reading until 24 hour reading. For pH6, the result showed that iron concentration is starting reduces after 6 hour .The different pattern for pH6 may due to problem in aeration process or during preparation of sample.

4.3.5 Effect of Colour with Time

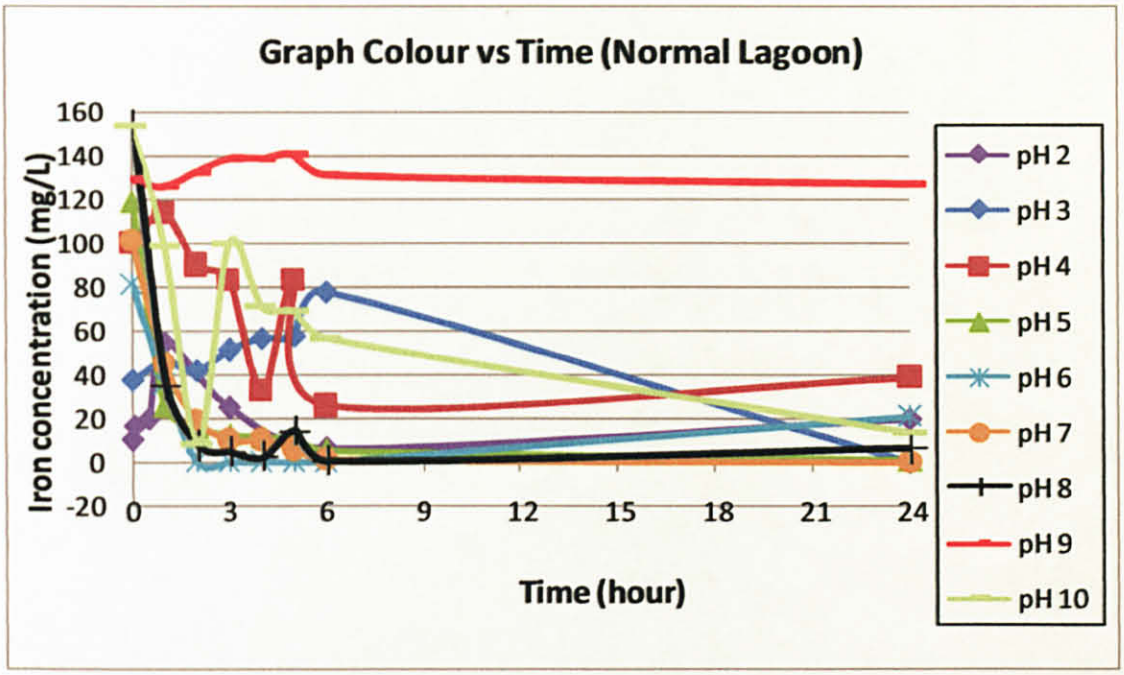


Figure 4.7: Graph colour vs. time (normal lagoon)

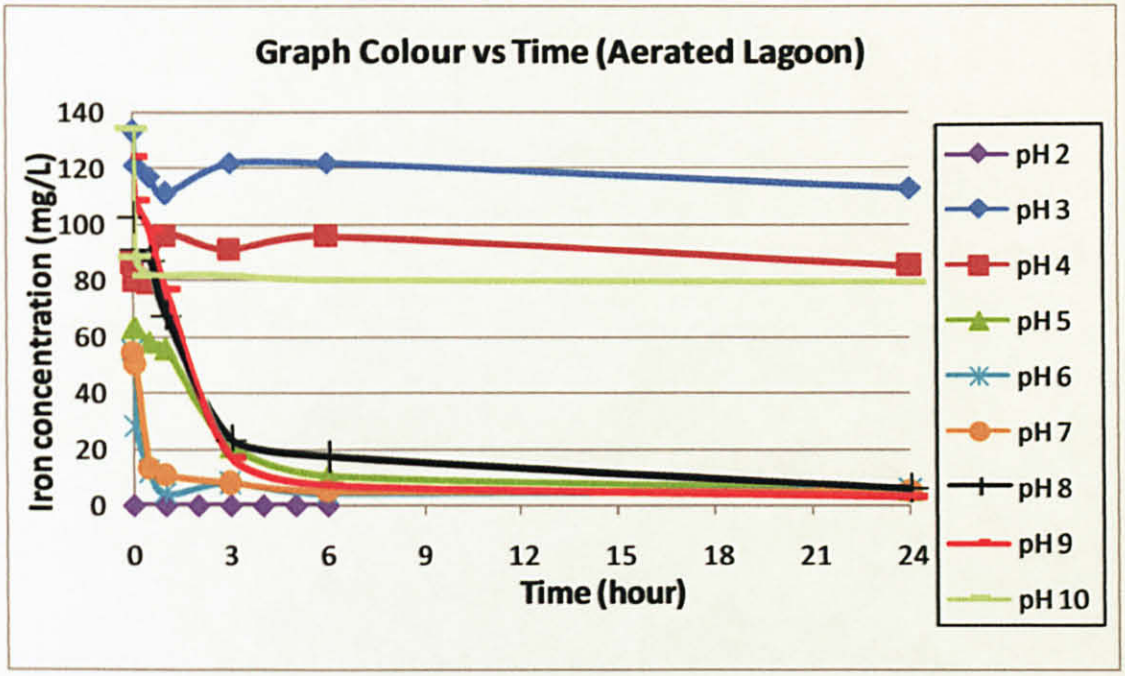


Figure 4.8: Graph colour vs. time (aerated lagoon)

Figure 4.7 and 4.8 showed the relation between colour and time for normal and aerated lagoon. For normal lagoon, pH7 reach allowable limit after 6 hour which 5mg/L Pt. For pH8, the colour value is 17mg/L Pt. The allowable limit colour for drinking water is 15 mg/L Pt. Colour for pH9 is can be assume same from initial until 24 hour.

For aerated lagoon, the graph pattern showed that colour keep decreasing after 1 hour aeration process except for pH3, 4 and 5. After 6 hour of aeration process, from pH5 until pH8, the colour reached allowable limit. The value of colour is between 0 and 5 mg/L Pt. Aeration process is much faster to reduce the colour of the sample. For example, at pH7, after 3 hour, the colour is 10mg/L Pt. It is also same with pH6 and pH8 with value of colour are 0mg/L Pt and 4mg/L Pt respectively.

4.3.6 Effect of Colour with pH

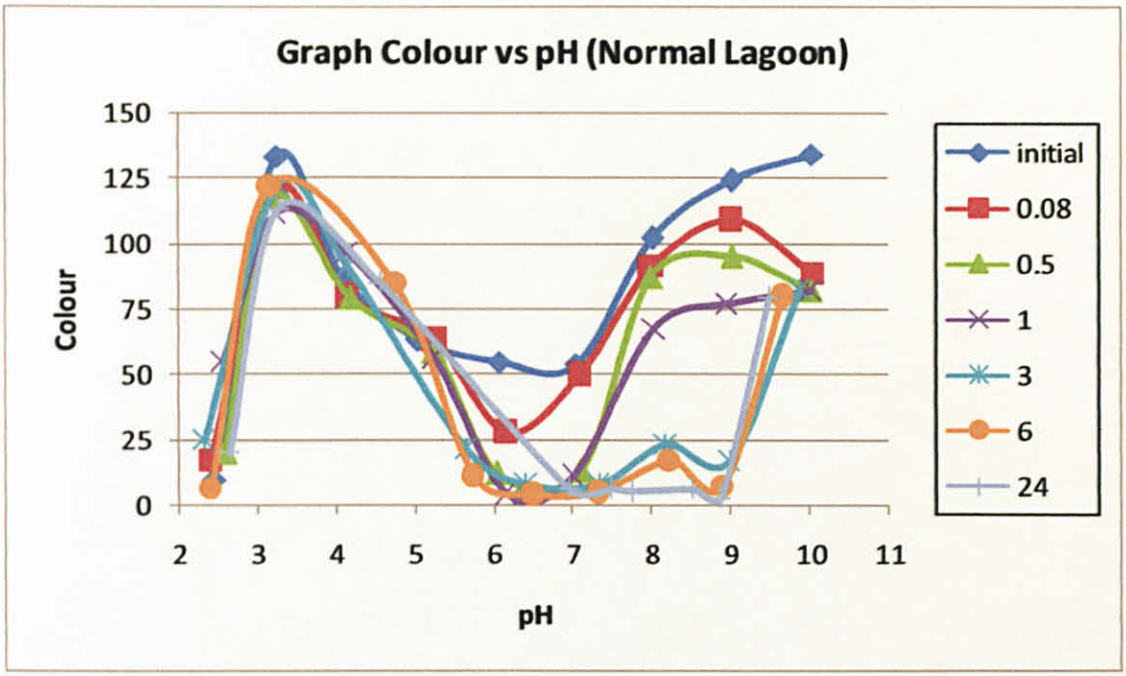


Figure 4.9: Graph colour vs. pH (normal lagoon)

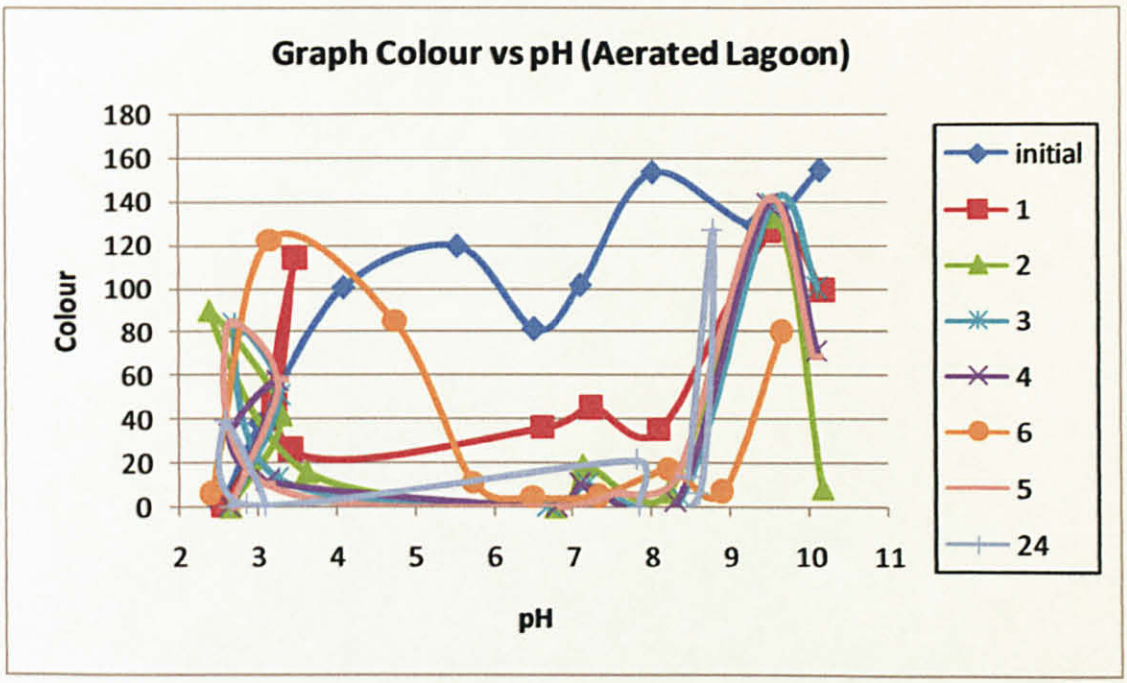


Figure 4.10: Graph colour vs. pH (aerated lagoon)

Figure 4.9 and 4.10 showed the relation between pH and colour for normal and aerated lagoon. For normal lagoon, for pH2 until pH6, the pattern is almost same at appointed time. After 6 hour, for pH5, 6 and 7, the result were reached allowable limit.

For aerated lagoon, the process of colour reducing is much faster. After 6 hour of aeration process, from pH5 until pH8, the colour reached allowable limit. The value of colour is between 0 and 5 mg/L Pt.

CHAPTER 5

ECONOMIC BENEFIT

5.0 Introduction

The economic benefit from groundwater is to support the increasing of water supply demand. To fulfill the demand, the authorities or other non-government bodies should find the alternative for surface water.

5.1 Treatment of Surface water and Groundwater

As mention before, the increases of water demand, the authorities can not depending on the surface water. Nowadays, the researches on the groundwater treatment in Malaysia keep increasing. Those researches will help the authorities to determine the alternative of using surface water.

Typical surface water treatment process as below:-

a) Aeration
b) Coagulation and Flocculation
c) Sedimentation
d) Filtration
e) Disinfection

Typical groundwater treatment process as below:-

a) Aeration
b) Settling
c) Filtration
d) Disinfection

Based on the treatment process, groundwater would skip coagulation, flocculation and sedimentation processes due to inexistence of suspended solids. Those processes contribute to the cost of surface water treatment.

The major costs for the groundwater treatment are to establish groundwater well and the treatment of metal solids such as iron. It is should be beneficial investment to treat the groundwater as alternative to surface water. The other alternative of using surface water and groundwater is seawater. The problem occurred from seawater is the bad quality of seawater. There are lot things to do such as desalination which will increase the cost treatment. These shows that groundwater treatment is more save cost compared to seawater treatment.

5.2 Sustainability and Negative Consequences

Groundwater is indeed a sustainable and reliable source of water supply if abstracted correctly with adequate controls and monitoring and using appropriate methods and technology. This fact has been proven in countries including Denmark where almost 100% of the water used is sourced from groundwater.

Other than Denmark, groundwater is also widely used in several other developed countries such as Germany, Switzerland, England, Australia, South Korea and the United States among others. It is widely considered a sustainable source of water when recharge rates are taken into consideration and monitored as groundwater abstraction is controlled by the authorities and the operator is required to monitor the impact of the groundwater abstraction on the environment.

There are some negative consequences from groundwater utilisation in the developed economies but these are small compared to the contributions made by groundwater to the socio-economic progress of these nations. Generally, these negative consequences occur under these circumstances:

a) The authority has no control on groundwater development;
b) Over-abstraction of groundwater occurs for many years; and
c) Geological conditions permit the consequences to happen.

CHAPTER 6

CONCLUSION

6.0 CONCLUSION

In conclusion, iron in groundwater is higher than standard drinking water. From experimental on the iron solution sample by using different pH, it can be conclude that the optimum pH to remove iron is pH7 because after 24 hour sample prepared, iron concentration reaches 0.2 mg/L for normal lagoon and 0.1 mg/L for aerated lagoon which is meet the standard requirement for drinking water. The reading for pH8 is 0.3 mg/ L for normal lagoon and 0.17 mg/L for aerated lagoon. Although pH8 reach the allowable limit, is will become costly because the treatment will involve another solution to increase the pH.

For colour criteria, the optimum pH is pH7. The reading of colour after 24 hour is 5 mg/L for normal lagoon and 0 mg/L for aerated lagoon.

By adding chemical solution or substances to the groundwater, the oxidation process could be fast at least by 3 hour of treatment.

CHAPTER 7

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Appendix A

Result of Iron concentration in sample

Table 6.1:- Total Iron Concentration in Sample from UTP well

Sample No.	Concentration (mg/L)
1	0.93
2	0.85
3	0.86
4	0.90
5	0.93
6	0.80

Appendix B

Result of turbidity in sample

Table 6.2:- Turbidity in sample

Test No.	Turbidity (NTU)	Test No.	Turbidity (NTU)
1	47.2	11	54.5
2	41.0	12	47.0
3	54.5	13	41.0
4	50.7	14	42.8
5	46.3	15	48.2
6	55.0	16	45.9
7	45.6	17	49.1
8	48.5		
9	45.7		
10	47.7		

Appendix C

Normal Lagoon detail result

Table 6.3:- Normal Lagoon detail result

pH 2

Time	pH	Conc.	Colour
hour		mg/L	PtCo
0.00	2.45	8.50	10
0.08	2.40	8.00	17
0.50	2.59	8.00	20
1.00	2.56	8.00	55
3.00	2.31	8.00	25
6.00	2.41	8.00	6
24.00	2.64	8.30	20

pH 3

Time	pH	Conc.	Colour
hour		mg/L	PtCo
0.00	3.25	8.00	133
0.08	3.25	7.90	121
0.50	3.19	7.80	117
1.00	3.23	7.80	111
3.00	3.28	7.60	122
6.00	3.16	7.10	122
24.00	3.28	7.80	113

pH 4

Time	pH	Conc.	Colour
hour		mg/L	PtCo
0.00	4.09	7.90	86
0.08	4.14	7.70	80
0.50	4.17	7.70	79
1.00	4.14	7.60	96
3.00	4.15	7.50	91
6.00	4.75	7.80	96
24.00	4.57	7.80	85

pH 5

Time	pH	Conc.	Colour
hour		mg/L	PtCo
0.00	5.05	6.60	63
0.08	5.25	6.30	63
0.50	5.25	6.20	58
1.00	5.23	6.20	56
3.00	5.66	1.80	21
6.00	5.74	1.30	11
24.00	6.97	0.50	6

pH 6

Time	pH	Conc.	Colour
hour		mg/L	PtCo
0.00	6.07	7.50	55
0.08	6.16	3.10	28
0.50	6.03	2.90	12
1.00	6.16	1.70	4
3.00	6.41	0.60	8
6.00	6.49	0.40	4
24.00	7.48	0.30	6

pH 7

Time	pH	Conc.	Colour
hour		mg/L	PtCo
0.00	7.04	7.30	54
0.08	7.09	5.10	50
0.50	7.11	3.60	13
1.00	7.01	3.40	11
3.00	7.34	1.60	8
6.00	7.33	0.40	5
24.00	7.76	0.23	5

pH 8

Time	pH	Conc.	Colour
hour		mg/L	PtCo
0.00	8.01	8.60	102
0.08	8.00	8.10	91
0.50	8.00	6.90	87
1.00	8.03	5.50	67
3.00	8.18	2.67	23
6.00	8.23	1.20	17
24.00	8.52	0.30	6

pH 9

Time	pH	Conc.	Colour
hour		mg/L	PtCo
0.00	9.01	8.73	124
0.08	9.01	7.83	109
0.50	9.01	6.73	98
1.00	8.96	5.13	77
3.00	8.98	2.20	17
6.00	8.90	0.50	7
24.00	8.87	0.27	3

pH 10

Time	pH	Conc.	Colour
hour		mg/L	PtCo
0.00	10.03	8.50	134
0.08	10.05	8.50	88
0.50	10.02	8.43	82
1.00	10.03	8.40	82
3.00	9.87	8.40	82
6.00	9.66	8.40	80
24.00	9.50	8.30	79

Appendix D

Aerated Lagoon detail result

Table 6.4:- Aerated Lagoon detail result

pH 2

Time	pH	Conc.	Colour
hour		mg/L	PtCo
0.00	2.54	8.73	0
1.00	2.55	8.50	0
2.00	2.65	8.40	0
3.00	2.65	8.37	0
4.00	2.64	8.17	0
5.00	2.64	8.80	0
6.00	2.64	8.80	0
24.00	2.64	8.90	0

pH 3

Time	pH	Conc.	Colour
hour		mg/L	PtCo
0.00	3.04	8.40	38
1.00	3.22	8.35	46
2.00	3.29	8.00	42
3.00	3.28	8.10	51
4.00	3.27	8.10	57
5.00	3.25	7.97	58
6.00	3.22	7.90	78
24.00	3.08	3.10	0

pH 4

Time	pH	Conc.	Colour
hour		mg/L	PtCo
0.00	4.08	7.97	100
1.00	3.48	7.60	114
2.00	2.38	7.50	90
3.00	2.70	7.30	83
4.00	2.64	6.90	33
5.00	2.62	7.43	83
6.00	2.60	7.70	26
24.00	2.59	7.80	39

pH 5

Time	pH	Conc.	Colour
hour		mg/L	PtCo
0.00	5.54	6.23	119
1.00	3.42	1.57	26
2.00	3.61	1.50	16
3.00	3.27	1.50	13
4.00	3.13	2.43	12
5.00	3.09	2.80	10
6.00	3.07	2.80	5
24.00	2.85	3.00	1

pH 6

Time	pH	Conc.	Colour
hour		mg/L	PtCo
0.00	6.52	4.33	81
1.00	6.63	1.70	36
2.00	6.78	1.10	0
3.00	6.70	0.97	0
4.00	6.81	0.77	0
5.00	6.82	0.70	0
6.00	6.79	0.40	0
24.00	7.80	0.35	21

pH 7

Time	pH	Conc.	Colour
hour		mg/L	PtCo
0.00	7.09	5.50	101
1.00	7.24	2.07	45
2.00	7.14	0.90	19
3.00	7.18	0.80	10
4.00	7.10	0.63	10
5.00	7.55	0.40	6
6.00	7.20	0.40	1
24.00	7.83	0.10	0

pH 8

Time	pH	Conc.	Colour
hour		mg/L	PtCo
0.00	8.01	6.57	153
1.00	8.10	2.53	35
2.00	8.23	1.30	7
3.00	8.36	0.80	4
4.00	8.30	0.40	2
5.00	8.32	0.30	14
6.00	8.35	0.40	0
24.00	8.60	0.17	6

pH 9

Time	pH	Conc.	Colour
hour		mg/L	PtCo
0.00	9.33	8.30	129
1.00	9.52	8.30	126
2.00	9.53	8.27	133
3.00	9.54	8.27	139
4.00	9.50	8.20	139
5.00	9.47	8.20	141
6.00	9.45	8.20	131
24.00	8.78	8.20	127

pH 10

Time	pH	Conc.	Colour
hour		mg/L	PtCo
0.00	10.13	8.30	154
1.00	10.18	5.80	99
2.00	10.17	4.83	8.4
3.00	10.12	4.20	100
4.00	10.11	4.20	71
5.00	10.06	4.17	69
6.00	9.86	3.60	57
24.00	8.47	1.30	14